SQXF Practice Coil Winding and Curing by LARP

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05/05/2014

Outline

- **SQXF Coil 1 Winding and Curing Procedure**
- **Pole Gap and Wedge Gap**
- **Problem and Solution**
- **Summary**
- **Schedule**

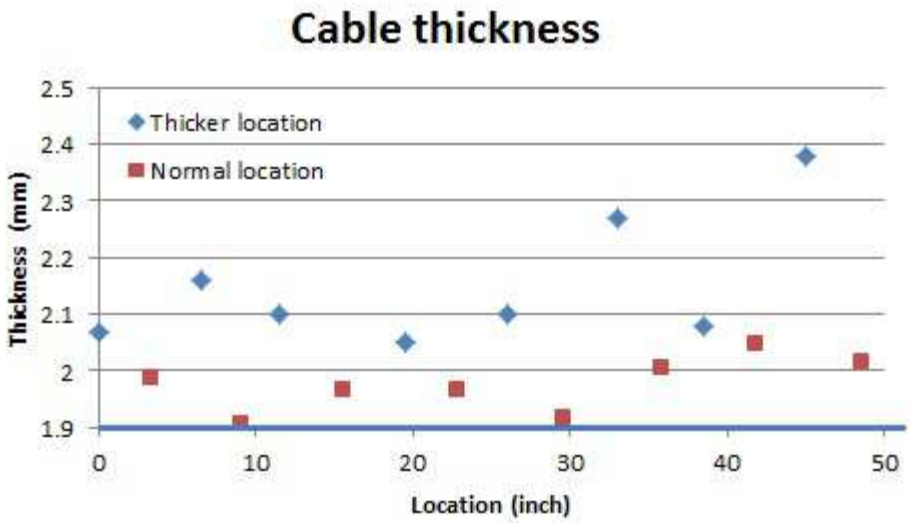
COIL 1 WINDING AND CURING PROCEDURE

Cable Re-spooling

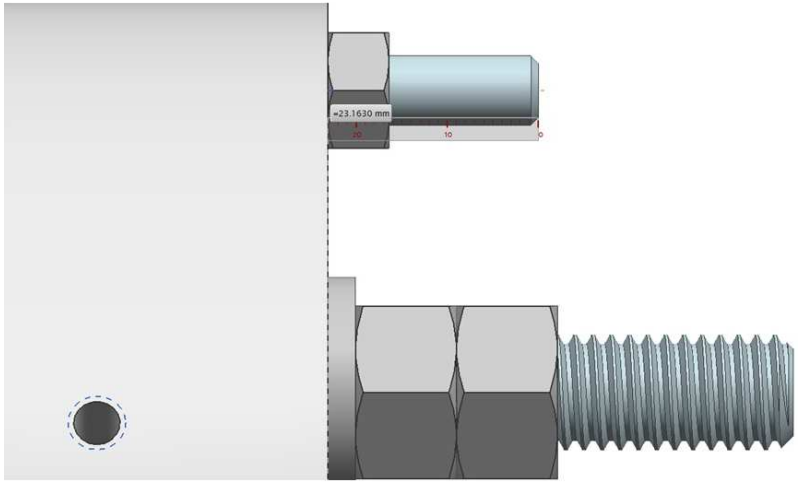
- Insulation wrapping machine
- 4 pulleys with last pulley reverse bending the cable
- Tension is provided by caterpillar
- During re-spooling for total length measurement and cable inspection, mark the split location for IL and OL spools.

Cable for Coil 1

- **Cable# 1050Z, total length 168.5 m**
- **IL used 56 m and OL used 70.7 m cable.**
- **Ten stack measurements shows the cable is within dimension tolerance**
- **However, during winding we found non-uniformity of cable thickness**
- **For next coil, cable# 1051Z, during re-spooling, we will verify the cable thickness uniformity.**



Winding Mandrel Setup



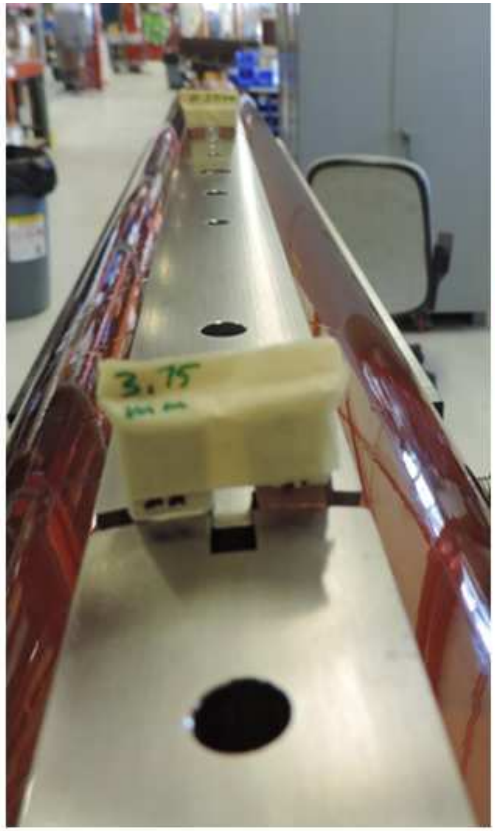
- The distance from the tensioner to the winding table is 1.5 m.
- Fixed the position of LE pole anchor (23.163mm to the last LE mandrel block)
- Counter weight for L1 (OL spool weight)
- 125 μm Kapton tape on top of the mandrel

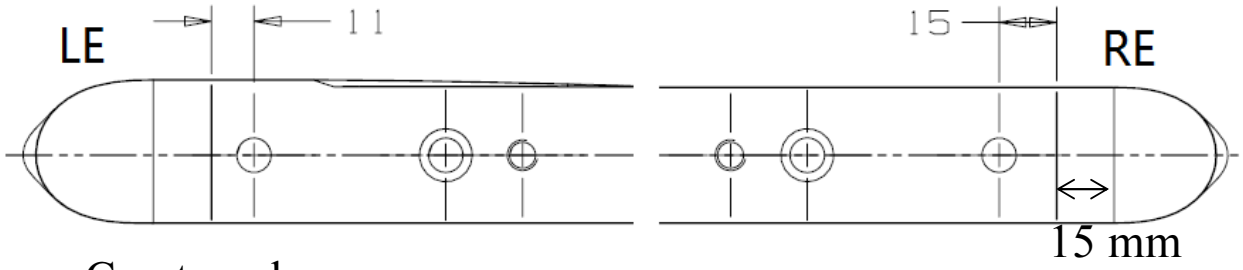
Coil Parts

- **Pole: align OL to IL with dowel pins**

- **Wedge: Cut both IL and OL wedges to the specified length. Insulate the wedges with 125 µm S2 glass sleeve, paint binder and cure at the ends.**
- **End parts: Visually check the coating, flexibility**

Pre IL Winding





- Create pole gaps
- Mark the VT location on the pole
- Mark lines on LE and RE poles to indicate the region where to paint binder and cure the end.
- Prepare and install winding tooling
- Wrap 2 turns of S2 glass tape (175 μm/layer) around poles starting from the ramp step.

Pre IL Winding

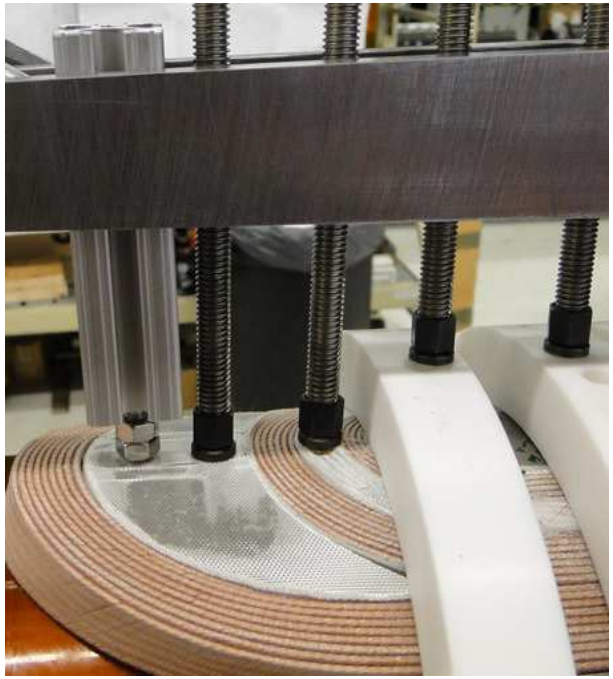
- Lay the cable on the transition side of the pole, and guide it through the ramp with the split mark as the reference.
- The rest of the S2 glass tape goes along with the cable for OL
- Use C-clamp to clamp the cable to Cable Ramp Clamping Plates
- Put the IL spool onto the tensioner with the thick edge of the conductor facing up and no twist. Put the OL spool on top of the winding tooling

IL Winding

- First two turns with winding tension 9 kg (20 lbs)
- Rotate mandrel and record the angle for each turn at both ends. Measure and record each turn location and angle at the ends
- Paint binder (CTD 1202) and cure each turn at the ends. Use the winding tool
- Install the VTs
- From turn 3, increase tension to 25 kg (55 lbs)
- Put one layer of 175 µm S2 glass tape in between each end part and the coil

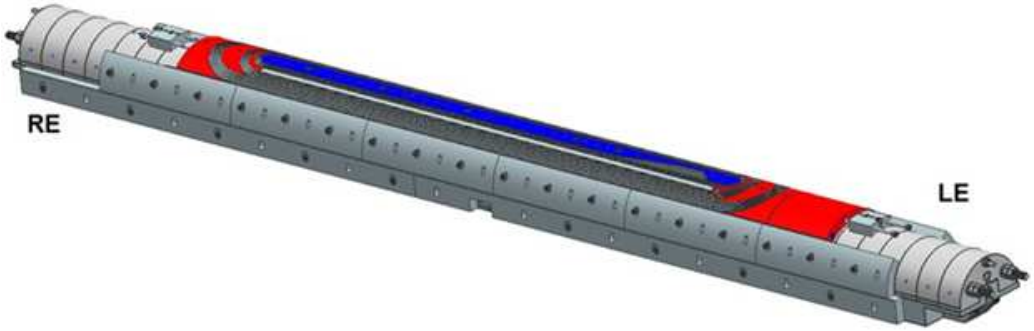
IL Winding

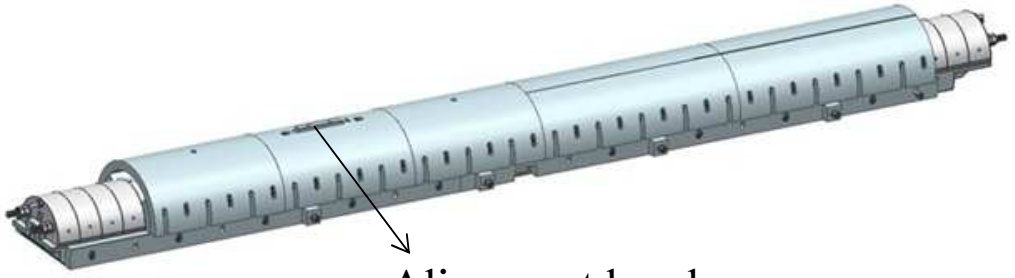
- **Use the alignment tool for each end spacer.**
  - Without the tool, the flexible end parts shifted along the winding direction and poke into the cable insulation causing part to cable short
- **Use Teflon and SS retainers to hold down the coil**
- **Use roller axle to push coil azimuthally.**



L1 Packaging for Curing

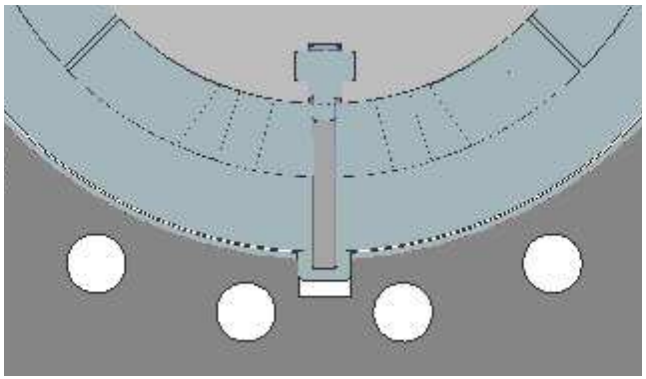
- Install the pushers from LE Transition side toward RE
- Remove SS core
- Install the pushers from RE Non-transition side toward LE
- Paint 84 g binder (CTD-1202)
- Shrink wrap the coil using 19 mm (3/4"), 50 μm thick Mylar with 50% overlap
- Install the curing spacers
- Install the curing shims and curing retainers



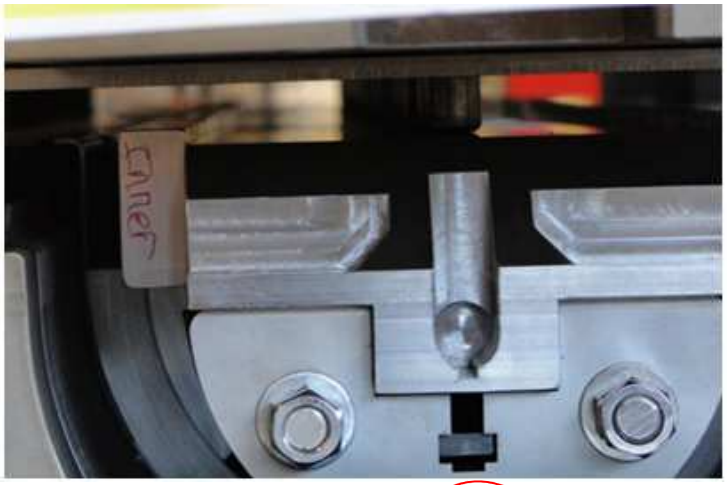


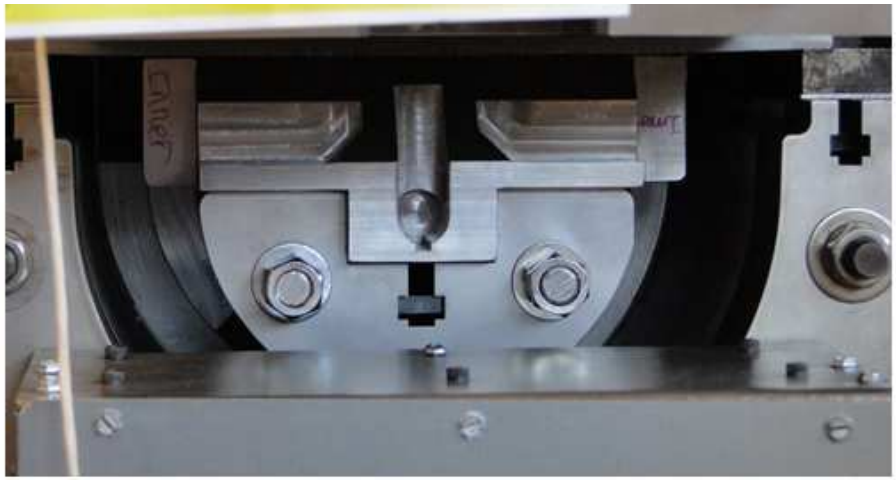
Coil Handling during W&C

- Crane + Slings to lift the coil and winding mandrel up from the winding table
- Install the spool support arm to the winding mandrel
- Attach the OL cable spool to the spool support arm
- Transfer to the rollover table and rotate 180 degree.
- Crane + Swivel D rings + Sling Hooks to lift the coil and put it inside the curing mold with alignment key bar.



L1 Curing

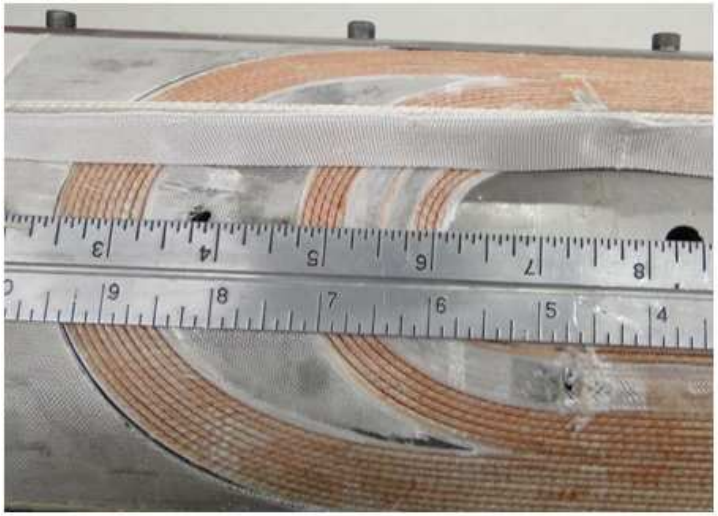


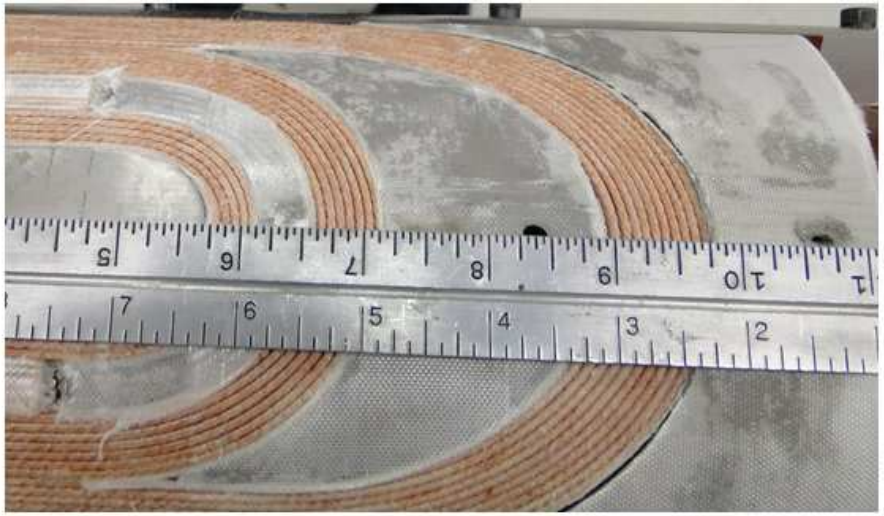


Mandrel Pressure:	☐ 500 psi	☐ 800 psi	☐ 1300 psi	☐ 1550 psi	☐ 1800 psi
Platten Pressure:	☐ 700 psi	☐ 1000 psi	☐ 1500 psi	☐ 1750 psi	☐ 2000 psi
Gap on Side:	A: ____ mm	A: ____ mm	A: ____ mm	A: ____ mm	A: ____ mm
	B: ____ mm	B: ____ mm	B: ____ mm	B: ____ mm	B: ____ mm

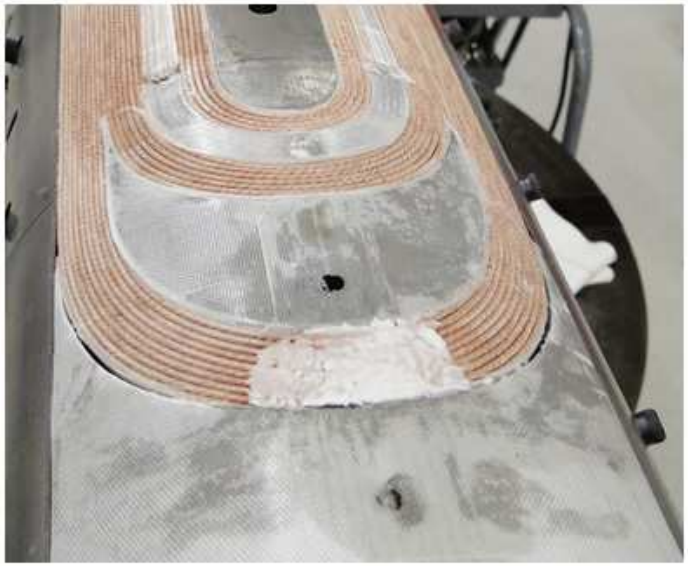
Coil stress ~ 10 MPa

After L1 Curing



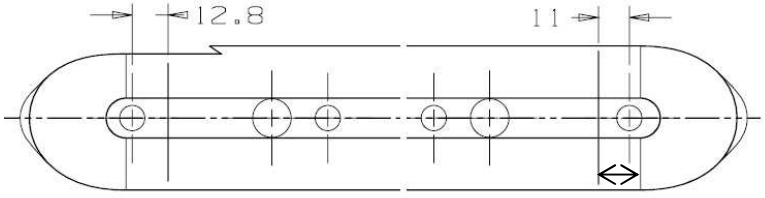


- No electrical short
- Prepare smashed S2 glass
- Soak with the binder
- Fill the un-even surface of the last conductor group on both ends
- Cure with heat gun
- Prepare two layer cured S2 glass interlayer insulation ~0.5 mm thick. (Use 47g matrix (31 g/m) over 1.35 m interlayer insulation and leave 0.18 m LE dry.)



L2 Winding Setup

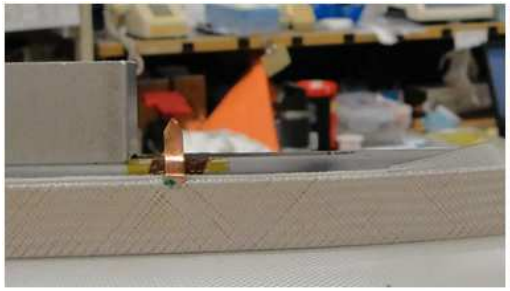
- Install L2 pole from RE using pins and screws
- Before pin and screw L2 LE pole, wrap 2 layers of 175 μm S2 Glass tape around L2 poles
- After pin and screw L2 LE pole, cut the insulation along the ramp edge
- Mark the VT location on the pole
- Mark lines on LE and RE poles to indicate the region where to paint binder and cure the end.

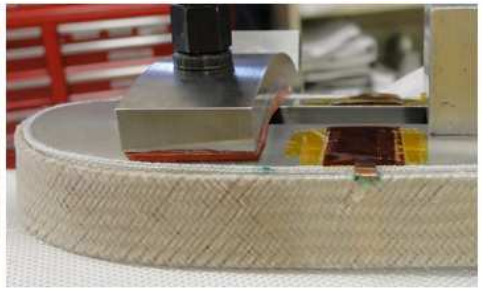


15 mm

L2 Winding

- First two turns with 9 kg (20lbs) winding tension
- From turn 3, increase the tension to 25 kg (55 lbs)
- Rotate mandrel and record the angle for each turn at both ends. Measure and record each turn location and angle at the ends
- Put one layer of 175 µm S2 glass tape in between each end part and the coil
- Paint binder (CTD 1202) and cure each turn at the ends. Use the winding tool
- Install the VTs





- Use the alignment tool for each end spacer. Use Teflon and SS retainers to hold down the coil. Use roller axle to push coil azimuthally.

L2 Packaging and Handling

- Trim the interlayer insulation
- Install the pushers from LE Non-transition side toward RE
- Remove SS core
- Install the pushers from RE Transition side toward LE
- Paint 107 g binder (CTD-1202)
- Shrink wrap the coil using 19 mm (3/4"), 50 µm thick Mylar with 50% overlap
- Install the curing spacers
- Install the curing shims and curing retainers
- Coil handling is the same as L1
- Two alignment key bars to curing mold (key bars are screwed to the poles via lifting tap holes)

Binder CTD-1202

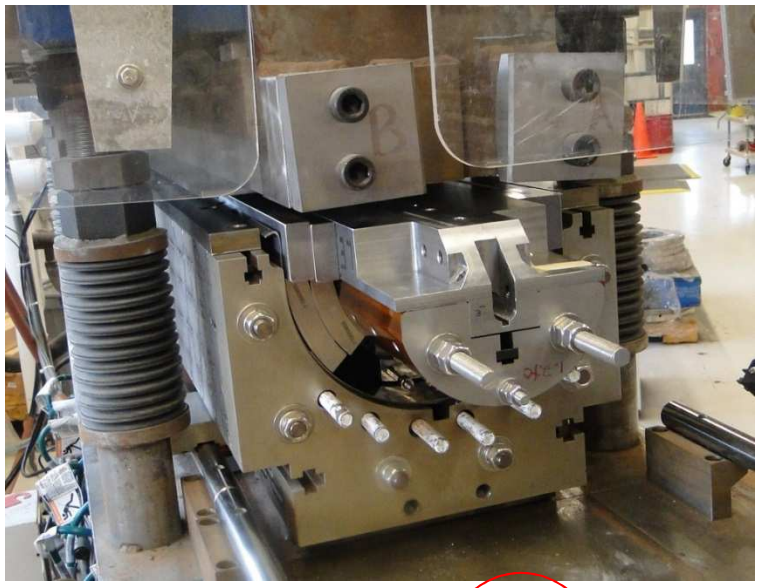
- **HQ**
  - L1: 43.8 g, 38 m cable → ~1.157 g/m
  - L2: 65.7 g, 48 m cable → ~1.38 g/m
- **LHQ**
  - L1: 140 g, 121 m cable → ~1.157 g/m
  - L2: 210 g, 152 m cable → ~1.38 g/m
  - Interlayer insulation: 25g/m

→ **1.25 g/m**

Soft brush

- **SQXF: 1.25x18.45/15.222 = 1.51 g/m**
  - L1: **84 g**, 55.6 m cable
  - L2: **107 g**, 70.8 m cable
  - Interlayer insulation: **25x75/60 = 31g/m**

L2 Curing



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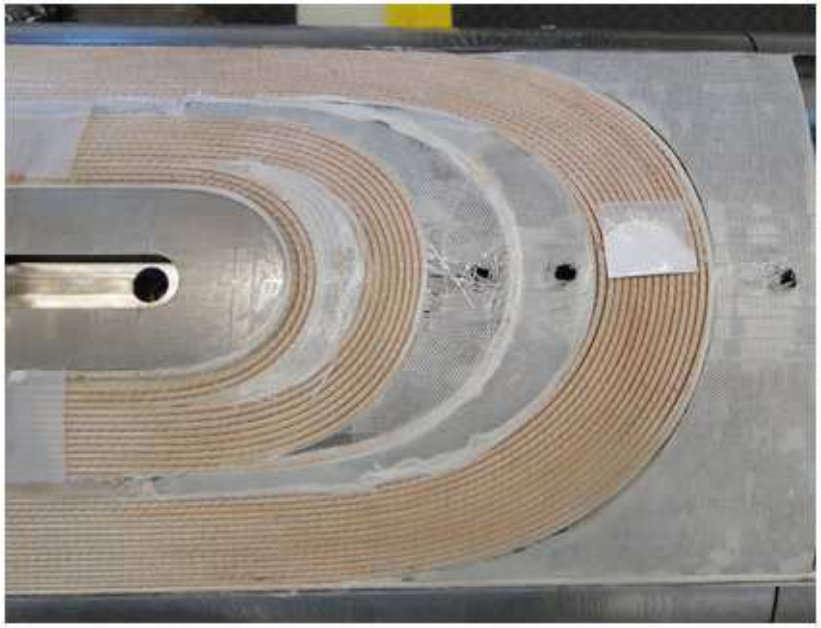
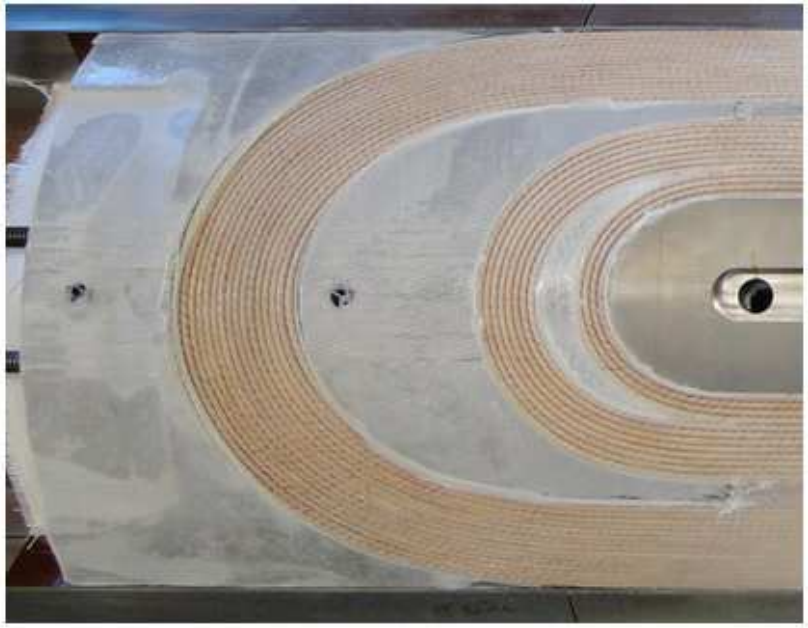
	B: ____ mm	B: ____ mm	B: ____ mm	B: ____ mm	B: ____ mm

Coil stress ~ 10 MPa

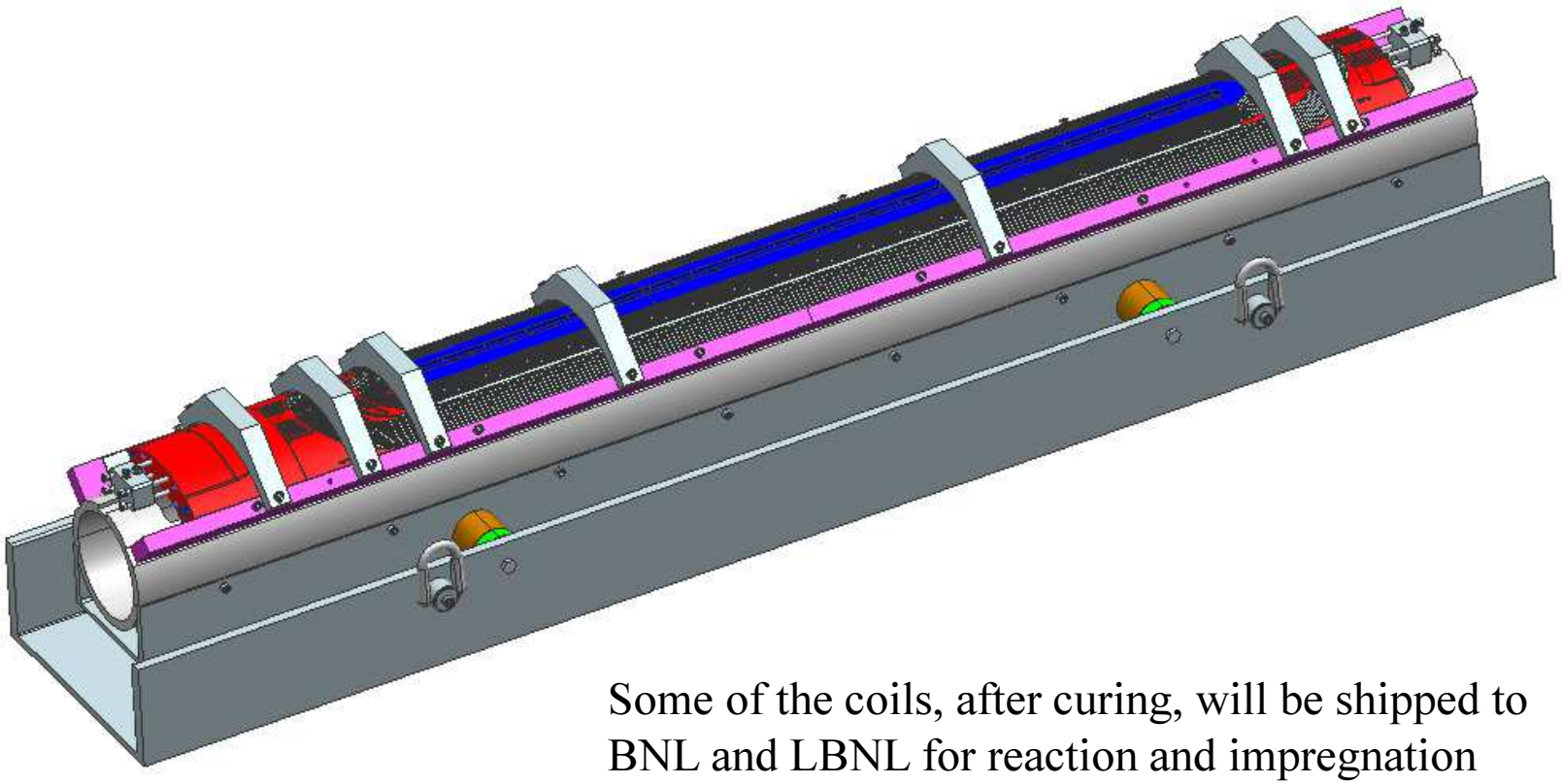
After L2 Curing





- No electrical short
- QA: coil resistance, Ls and Q value measurement
- Coil dimension measurement
- Release tension, and measurement the pole gap and wedge gap
- Prepare for shipping or reaction.

Coil Shipping after Curing



Some of the coils, after curing, will be shipped to BNL and LBNL for reaction and impregnation

POLE GAP AND WEDGE GAP

HQ Pole Gap

Measurement Analysis: Pole Gap

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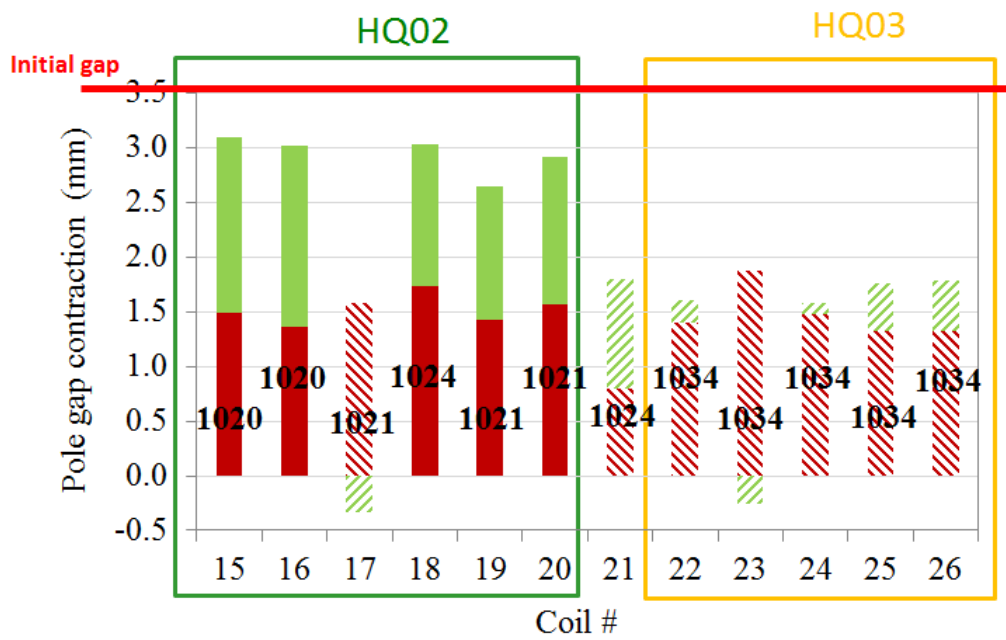
U.S. LARP

Total pole gap contraction (cable relaxation + reaction)

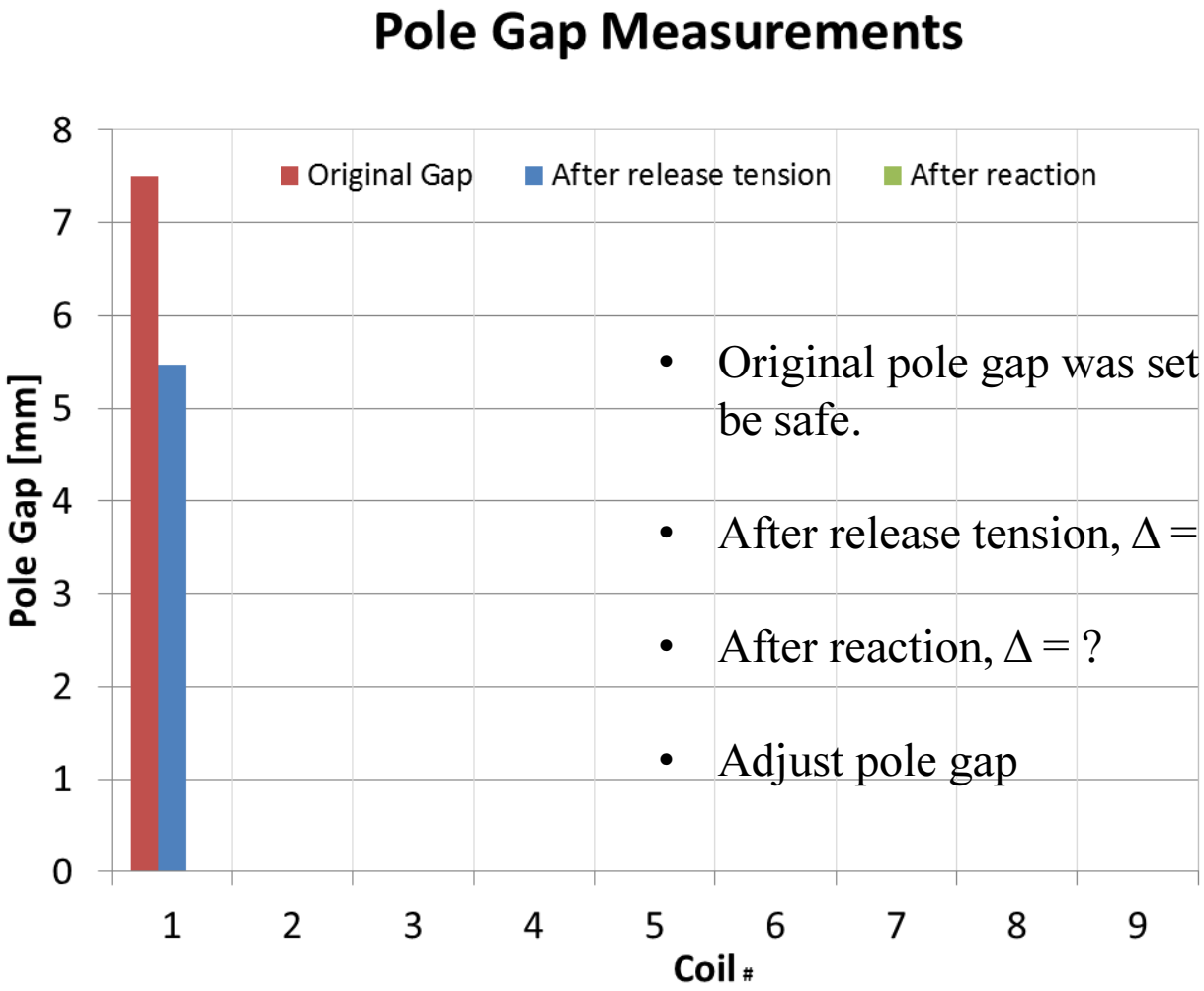


Average cable relaxation		
Sleeve insulation	**1.51**	mm
Braided insulation	**1.50**	mm

Average coil contraction after reaction		
Sleeve insulation	**1.42**	mm
Braided insulation	**0.10**	mm

→ Reproducibility (even with different cable)
→ Ti doped cable (coil 18) has a similar gap contraction than Ta coils (all other)
→ Difference in gap contraction after reaction likely due to the different type of insulation used.

SQXF Coil 1 Pole Gap



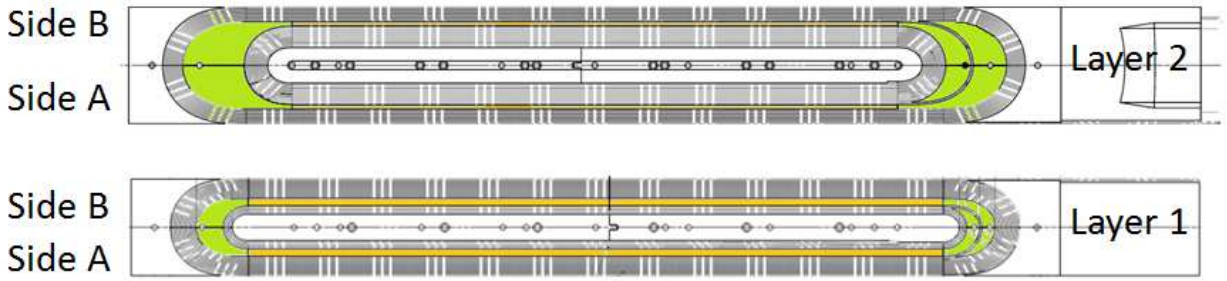
- Original pole gap was set as 7.5 mm to be safe.
- After release tension, $\Delta = 2.03$ mm
- After reaction, $\Delta = ?$
- Adjust pole gap

HQ Wedge Gap

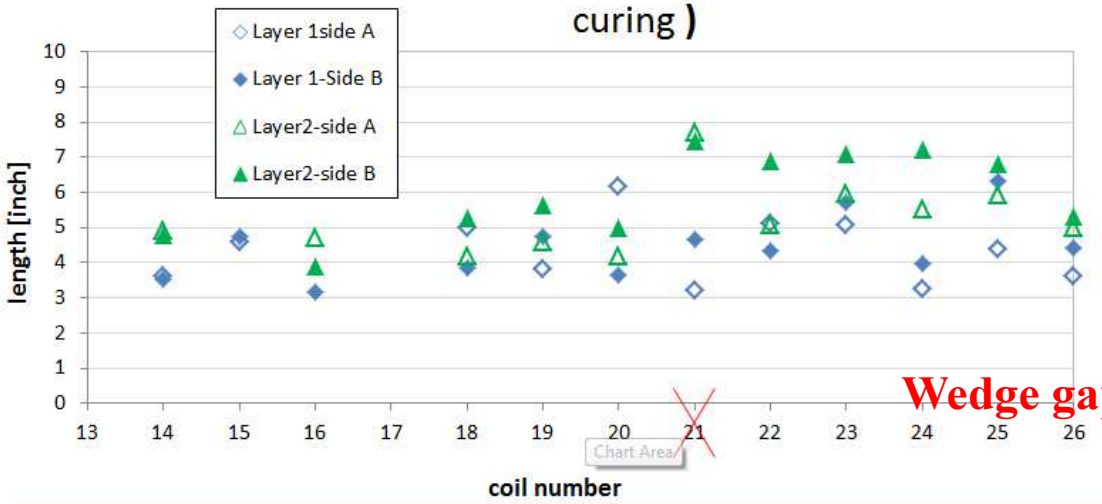
Wedge to spacer gap

Lawrence Berkeley National Laboratory

U.S. LARP



Spacer/wedge gap (measured after winding/bef. curing)



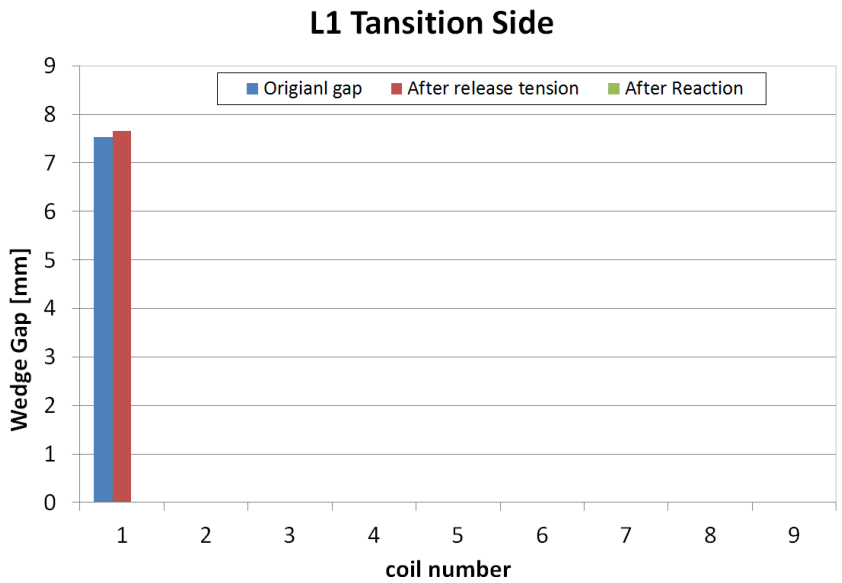
Average values

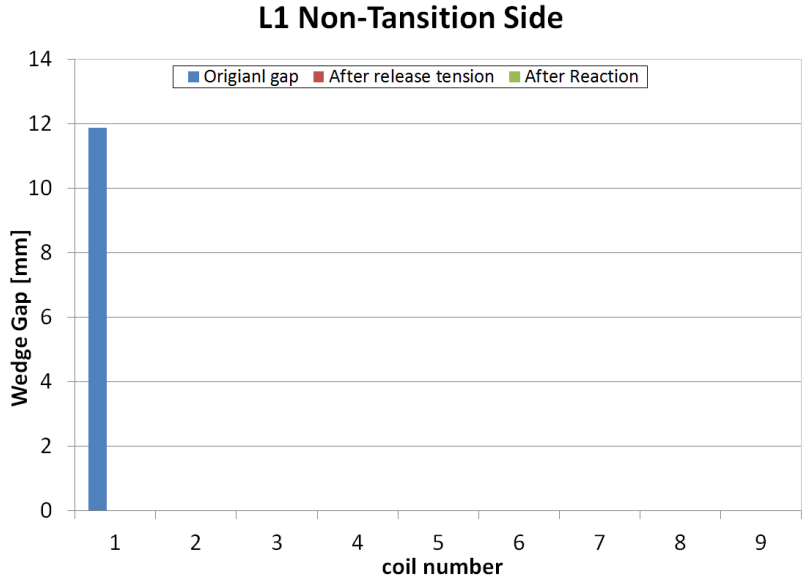
Pole Gap : 3.5 mm
L1 wedge gap : 4.6 mm

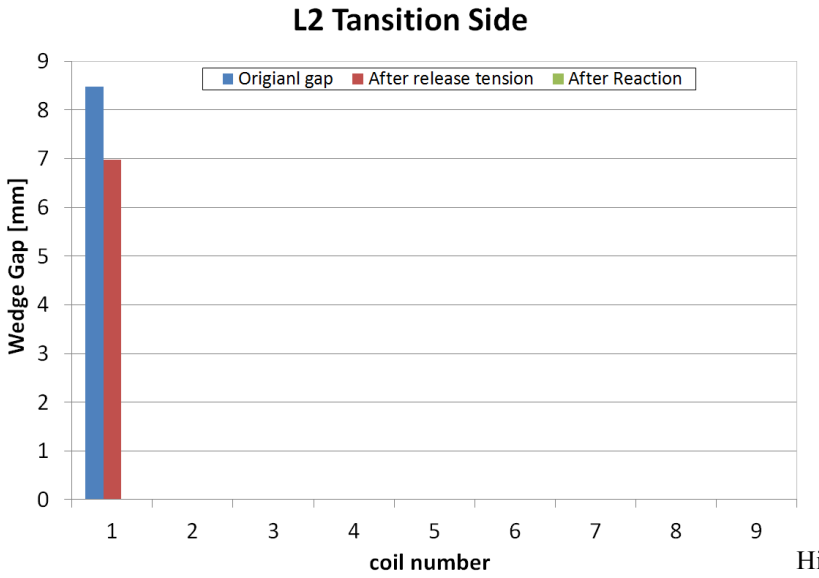
L2 wedge gap : 5.4 mm

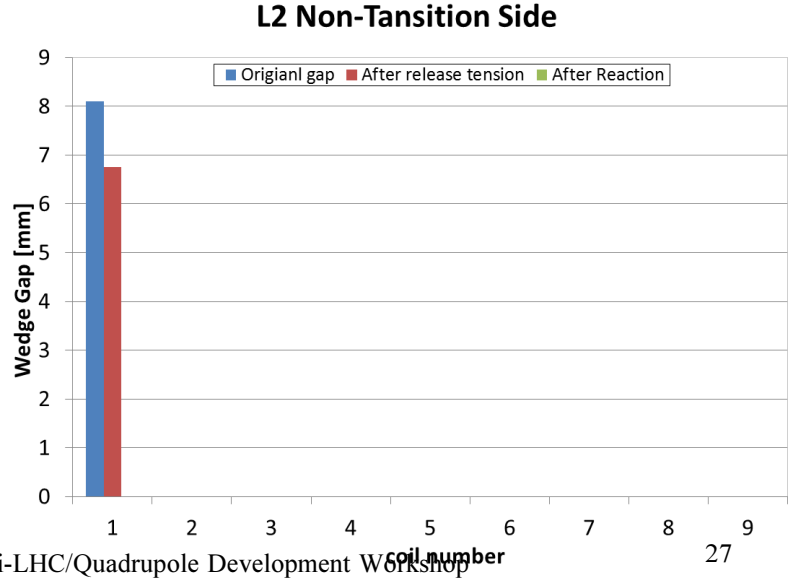
Wedge gap = minimum pole gap +3 mm

SQXF Coil 1 Wedge Gap



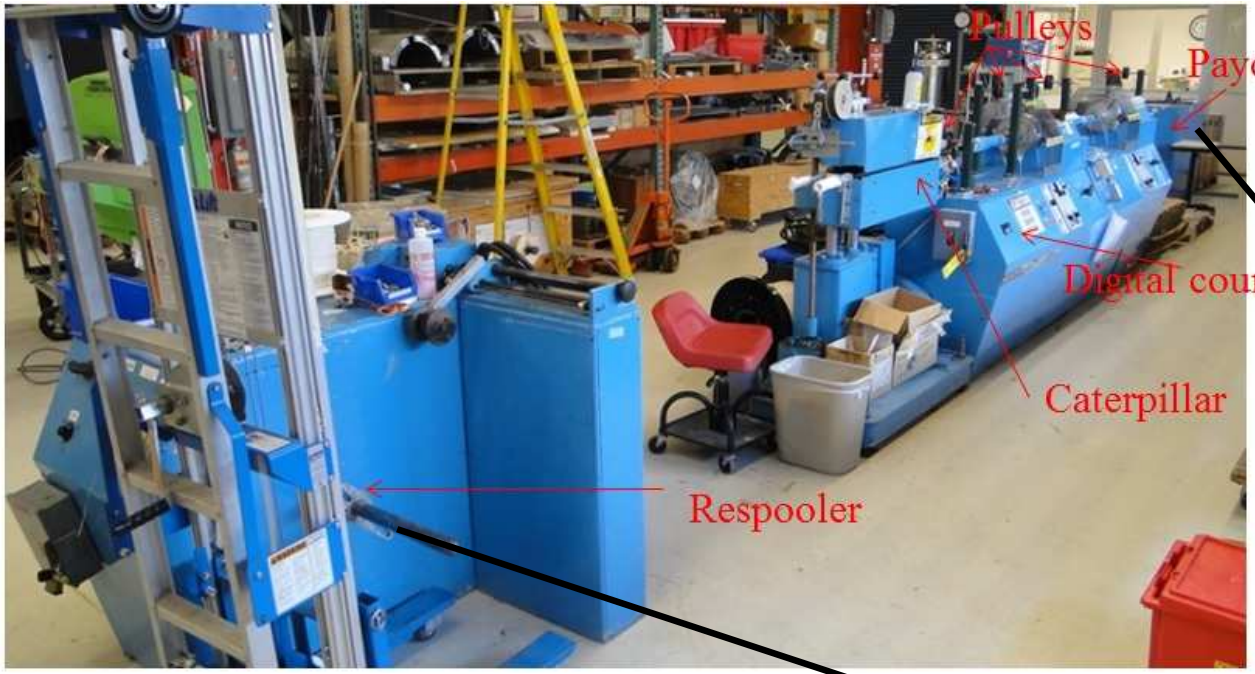






COIL 1 PROBLEM AND SOLUTION

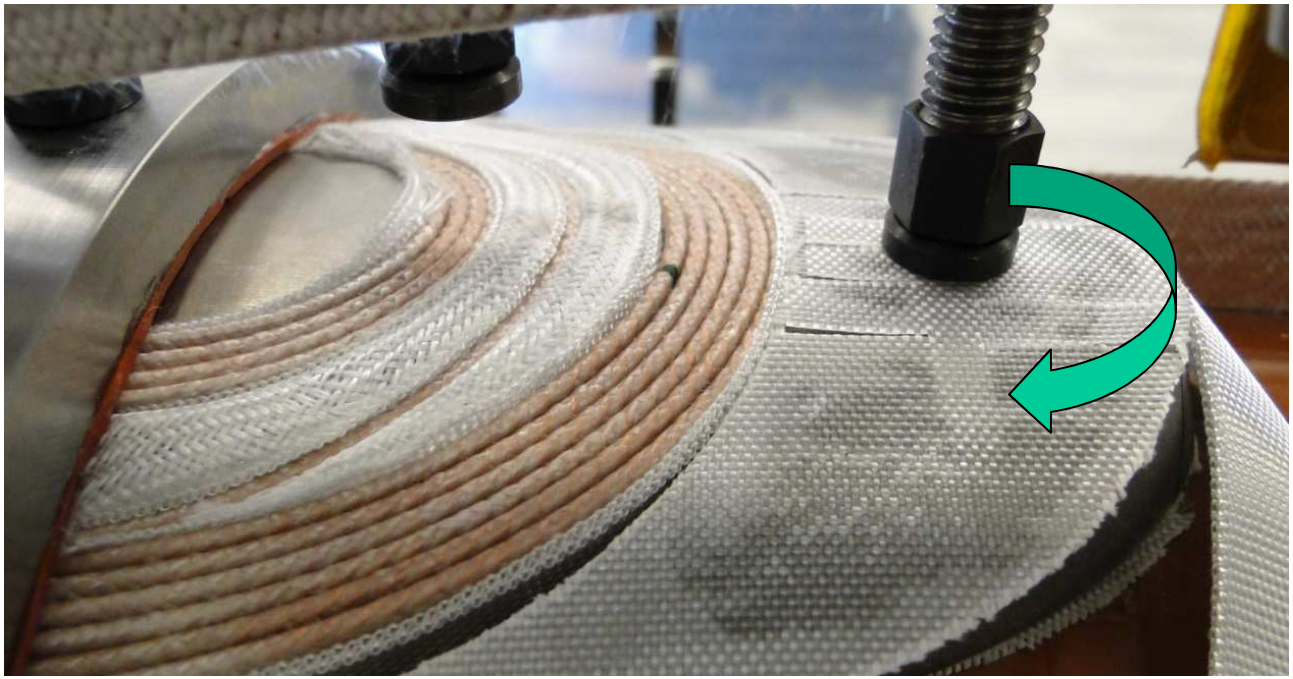
Cable Re-spooling

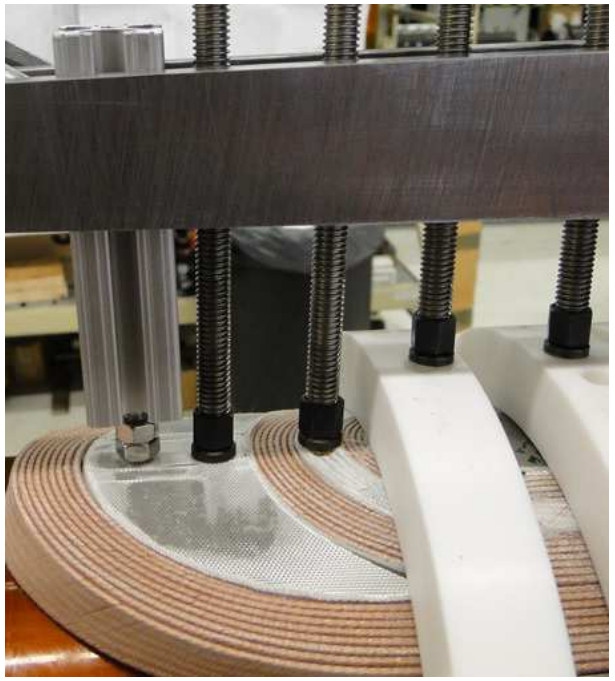


Tension is provided by payout and respooler

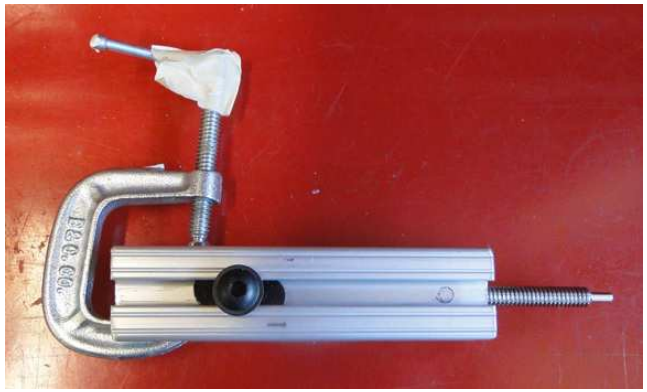
Digital counter, measures in meters and tenths

Flexible end parts



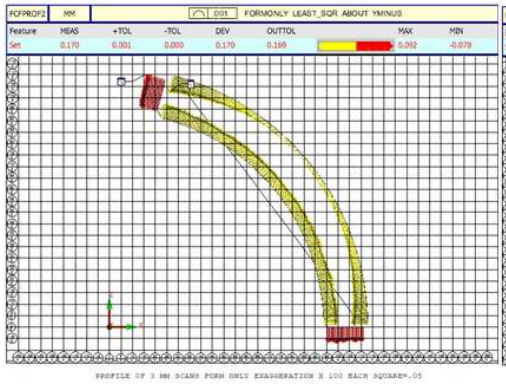


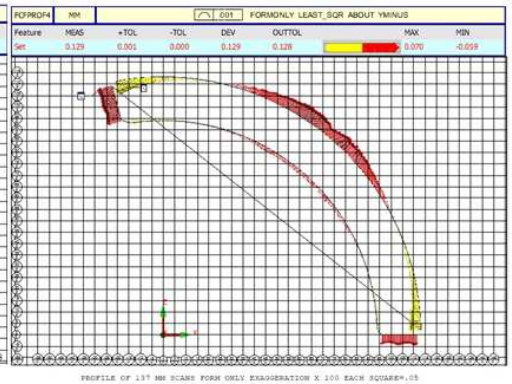
- The flexible end parts shifted along the winding direction and poke into the cable insulation causing part to cable short
- Solution: Alignment tool (80/20 Al frame, threaded rod with one end machined down as a 3 mm pin, double nuts, and C-clamp). After using the tooling, no short happened again.

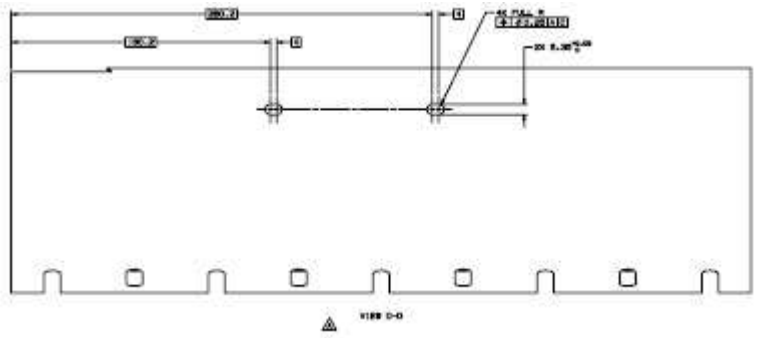


Layer jump

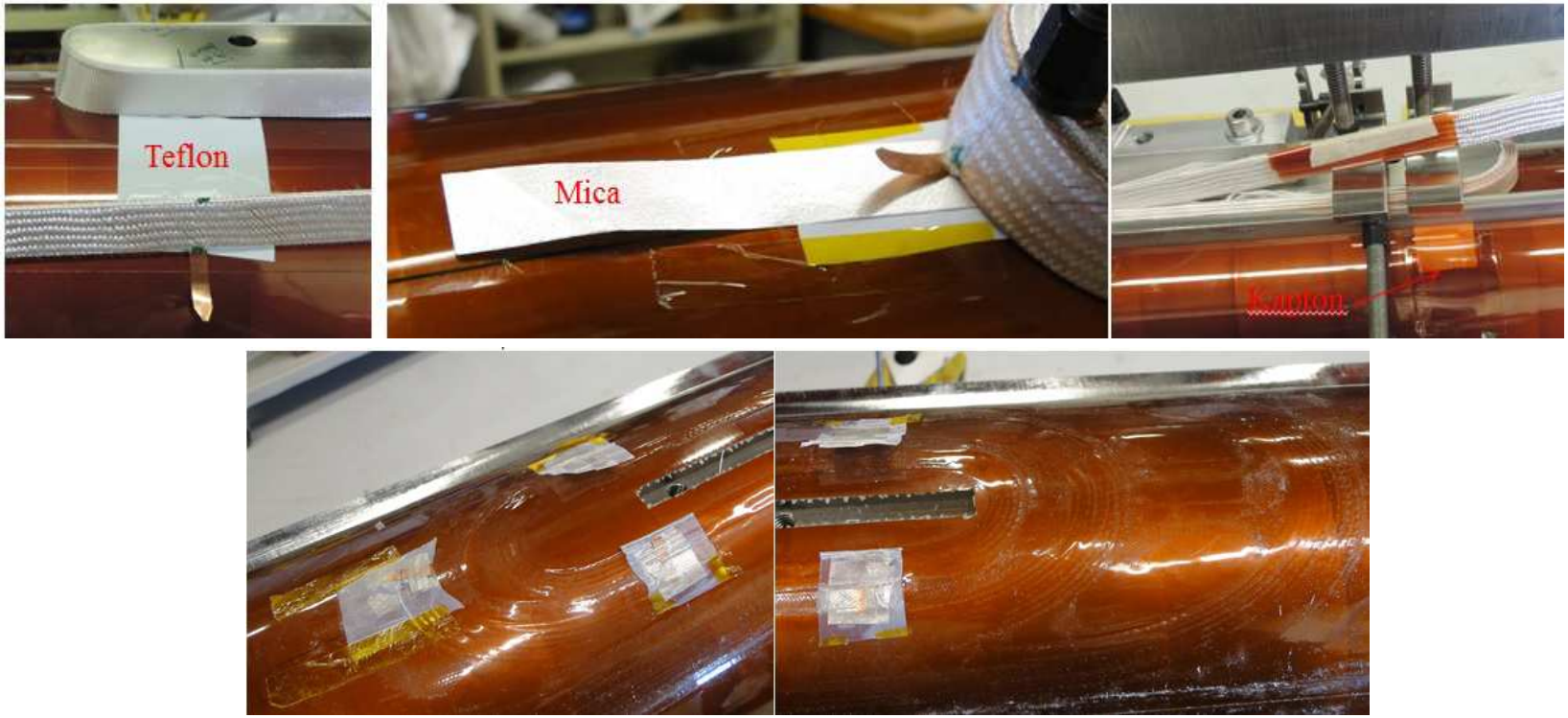
- After curing, the layer jump cable was over pushed by the curing spacer
  Solution: Four half shell curing spacers were returned to the vendor for rework remove material from mid-plane and add two alignment pin slots
  - Use pins to position the curing spacer
  - Use side pusher bars as stop bar





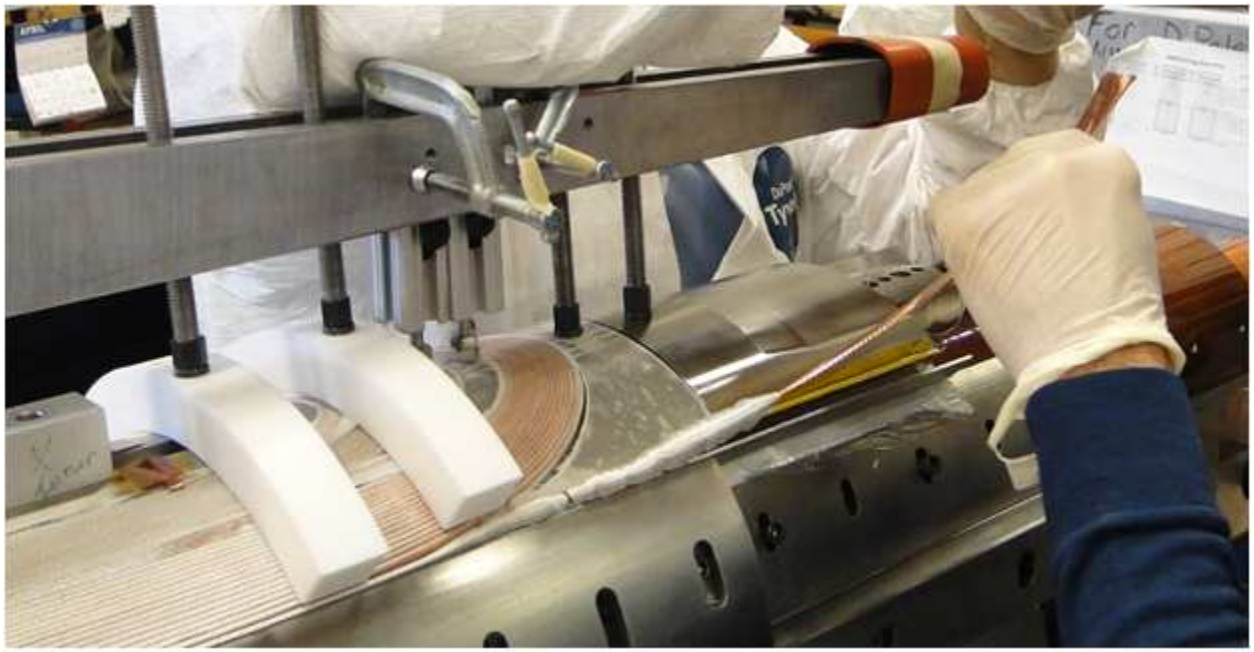


IL Voltage Taps



- Two VTs were broken due to the high pressure during curing.
  - No teflon tap and Mica, and shorten the VT flag
  - Move all the VTs to coil straight section

Remove SS Core



- Hard way bending the cable to remove the core.
- Solution: After installing one side pushers, turn off the tensioner, cut the cable, back-wind the coil, remove the SS core, and then install the other side pushers.

Binder for Curing L2

- Separation between the wedge and the turn, and between the pole and the turn
- Solution: increase from 107 g to 120 g for the next coil

Summary

- **SQXF coil 1 winding and curing was finished**
- **All the tooling was checked. Curing spacers need rework. Curing press will be upgrade after Coil 2**
- **The winding and curing procedure was followed through the fabrication. All the comments and modification will be updated for the next coil**
- **We are ready to fabricate Coil 2 which is planned as the mirror coil.**

Schedule

	Task Name	Duration	Start	Finish	Predece
144	**Practice Coil #L1**	**154 days**	**Wed 3/5/14**	**Mon 10/6/14**	**38,81,23**
145	**Coil Wind / Cure**	**27 days**	**Wed 3/5/14**	**Thu 4/10/14**	**106,112**
152	Prepare Reaction Tooling	10 days	Fri 4/11/14	Thu 4/24/14	145
153	Coil shipment	12 days	Fri 4/25/14	Mon 5/12/14	152
154	Coil Reaction	33 days	Tue 5/13/14	Thu 6/26/14	153
155	Coil Impreg	45 days	Fri 6/27/14	Thu 8/28/14	34,154
156	Coil shipment	12 days	Fri 8/29/14	Mon 9/15/14	155
157	Coil inspection	15 days	Tue 9/16/14	Mon 10/6/14	156
158	plasma coating end parts for PC#2	15 days	Tue 4/15/14	Mon 5/5/14	118
159	**Coil #L2 (for mirror test)**	**88 days**	**Mon 5/12/14**	**Wed 9/10/14**	**82**
160	Coil Wind / Cure	20 days	Mon 5/12/14	Fri 6/6/14	158FS+4
161	Coil React	23 days	Mon 6/9/14	Wed 7/9/14	160
162	Coil Impreg	35 days	Thu 7/10/14	Wed 8/27/14	161
163	Coil instrumentation (FNAL)	10 days	Thu 8/28/14	Wed 9/10/14	162
164	**SQXF mirror**	**85 days**	**Thu 9/11/14**	**Wed 1/7/15**	**53,159**
170	plasma coating end parts for PC#3	15 days	Tue 5/20/14	Mon 6/9/14	119
171	Curing Mold Upgrade	25 days	Mon 6/9/14	Fri 7/11/14	160
172	SQXF1 Coils (3-6) Readiness Review	1 day	Mon 7/14/14	Mon 7/14/14	171
173	**Coil #L3**	**100 days**	**Tue 7/15/14**	**Mon 12/1/14**	**83**
174	Coil Wind / Cure	20 days	Tue 7/15/14	Mon 8/11/14	170,172
175	Coil shipment to LBNL	12 days	Tue 8/12/14	Wed 8/27/14	174
176	Coil React	23 days	Thu 8/28/14	Mon 9/29/14	175
177	Coil Impreg	35 days	Tue 9/30/14	Mon 11/17/14	176,35
178	Coil instrumentation	10 days	Tue 11/18/14	Mon 12/1/14	177,156
179	plasma coating end parts for PC#4	15 days	Mon 7/14/14	Fri 8/1/14	120
180	**Coil #L4**	**127 days**	**Tue 8/12/14**	**Wed 2/4/15**	**84**
181	Coil Wind / Cure	15 days	Tue 8/12/14	Mon 9/1/14	174,179
182	Coil shipment to BNL	12 days	Tue 9/2/14	Wed 9/17/14	181
183	Coil React	33 days	Thu 9/18/14	Mon 11/3/14	182
184	Coil Impreg	45 days	Tue 11/4/14	Mon 1/5/15	183
185	Coil shipment	12 days	Tue 1/6/15	Wed 1/21/15	184
186	Coil instrumentation	10 days	Thu 1/22/15	Wed 2/4/15	178,185
187	plasma coating end parts for PC#5	15 days	Mon 8/18/14	Fri 9/5/14	121
188	**Coil #L5**	**101 days**	**Wed 10/1/14**	**Wed 2/18/15**	**85**
189	Coil Wind / Cure	15 days	Wed 10/1/14	Tue 10/21/14	181,187
190	Coil React	23 days	Wed 10/22/14	Fri 11/21/14	189,161
191	Coil Impreg	35 days	Mon 11/24/14	Fri 1/9/15	190
192	Coil shipment	12 days	Mon 1/12/15	Tue 1/27/15	191
193	Coil instrumentation	10 days	Thu 2/5/15	Wed 2/18/15	192,186
194	plasma coating end parts for PC#6	15 days	Tue 12/9/14	Mon 12/29/14	123
195	**Coil #L6**	**95 days**	**Tue 12/30/14**	**Mon 5/11/15**	**86**
196	Coil Wind / Cure	15 days	Tue 12/30/14	Mon 1/19/15	189,194
197	Coil shipment	12 days	Tue 1/20/15	Wed 2/4/15	196
198	Coil React	23 days	Thu 2/5/15	Mon 3/9/15	176FS+2
199	Coil Impreg	35 days	Tue 3/10/15	Mon 4/27/15	198
200	Coil instrumentation	10 days	Tue 4/28/15	Mon 5/11/15	193,199